**P-10**

# Application of scanning probe microscopy methods to control the synthesis technology of multilayer structures with Bi-substituted iron garnets

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Authors present the synthesis technology in which a lower surface roughness of the layers in multilayer structure with Bi-substituted iron garnets can be achieved through simultaneous crystallization annealing of the bottom Bi-substituted iron garnet layer and the top layer of $SiO_2$.

The search for new synthesis techniques of iron garnets layers with a smooth surface is relevant for creating multilayer structures, for example, the structures of magnetophotonic and magnetoplasmonic crystals with Bragg mirrors of titanium and silicon oxides. Typical grain size of the iron garnet polycrystalline films deposited by reactive ion-beam sputtering and crystallized in air varies from several tens to several hundred nanometers, depending on the film composition and duration of annealing [1]. As will be shown below, all layers deposited on iron garnet film inherit its roughness. Rough surface of the layers can substantially weaken interference, diffraction, and plasmonic effects, and create an effective absorption of a light wave. The main goal of the work was to develop the synthesis technology, in which as much as possible low surface roughness of iron garnet layers and the layers of a multilayer structure could be achieved.

Figure 1 shows the surface topography of the film of composition $Bi_{1.0}Y_{0.5}Gd_{1.5}Fe_{4.2}Al_{0.8}O_{12}$ on $SiO_2$ layer and a multilayer structure $(TiO_2 / SiO_2)^7 / Bi_{1.0}Y_{0.5}Gd_{1.5}Fe_{4.2}Al_{0.8}O_{12} / SiO_2$ on monocrystalline gadolinium gallium garnet (GGG) substrate. In the first case the thickness of the garnet film is 70 nm. In the structure iron garnet layer were crystallized before deposition of $SiO_2$ layer, and the thicknesses of layers are $(74\text{ nm} /115\text{ nm})^7$ / 108 nm / 140 nm, respectively. Investigation of surface morphology and roughness parameters of samples was carried by scanning probe microscope NTEGRA. RMS roughnesses of the film and structure surfaces are 11.4 nm and 6.1 nm, correspondingly. Although the grain density in the images differs due to the difference in thickness of garnet film and annealing time in the two samples, the surface character is identical.

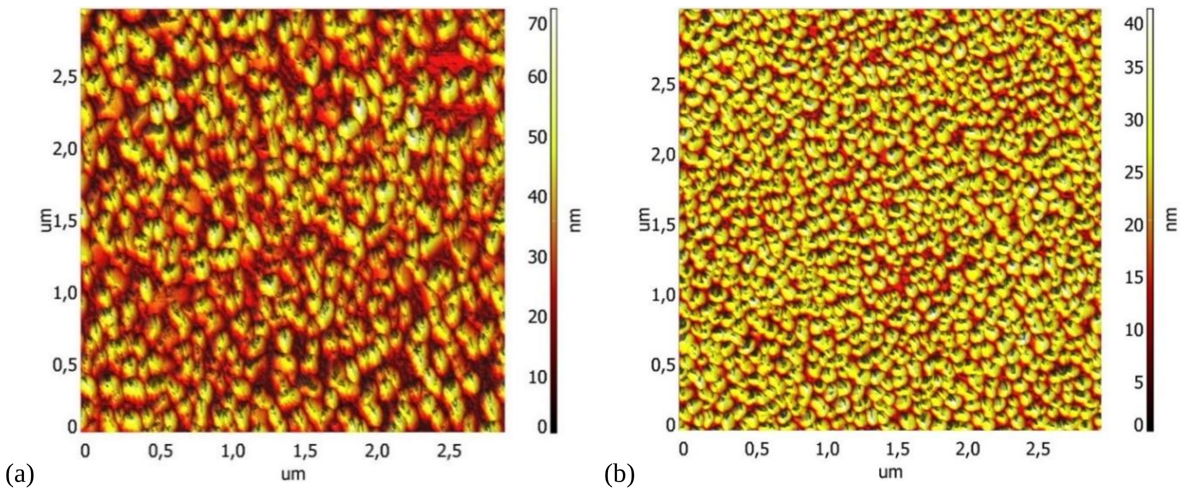


Figure 1. Topography of iron garnet film of composition $Bi_{1.0}Y_{0.5}Gd_{1.5}Fe_{4.2}Al_{0.8}O_{12}$ on $SiO_2$ layer (a) and a multilayer structure $(TiO_2 / SiO_2)^7 / Bi_{1.0}Y_{0.5}Gd_{1.5}Fe_{4.2}Al_{0.8}O_{12} / SiO_2$ on GGG substrate (b).

In order to reduce the roughness of layers in multilayer structure, it has been proposed to crystallize a layer of iron garnet already pre-coated with the next layer of the structure, for example, silicon oxide. For successful crystallization, an amorphous layer of garnet should be deposited on the substrate or sub-layer with garnet structure. To test the proposed method, single-layer film of composition $Bi_{1.5}Gd_{1.5}Fe_{4.5}Al_{0.5}O_{12}$ and double-layer film of composition $Bi_{1.5}Gd_{1.5}Fe_{4.5}Al_{0.5}O_{12}$ / $SiO_2$ were synthesized on monocrystalline GGG substrates with crystallographic orientation of (111). Crystallization annealing of the films occurred at a temperature of 680 $^{o}$C. The thickness of the garnet layer in both samples is 140 nm. The thickness of $SiO_2$ layer is 100 nm. Figures 2-3 show the topography of single- and double-layer films at different scan sizes. RMS roughnesses of corresponding surfaces are 7.4 nm and 1.4 nm for scans of 3 x 3 μm (Figure 2) and 9.4 nm and 2.1 nm for scans of 5 x 5 μm (Figure 3). The character of the surface morphology of the samples indicates the formation of grain clusters in garnet films. The effective crystallization of garnet film under layer of silicon oxide was confirmed by measurements of magneto-optical hysteresis loops.

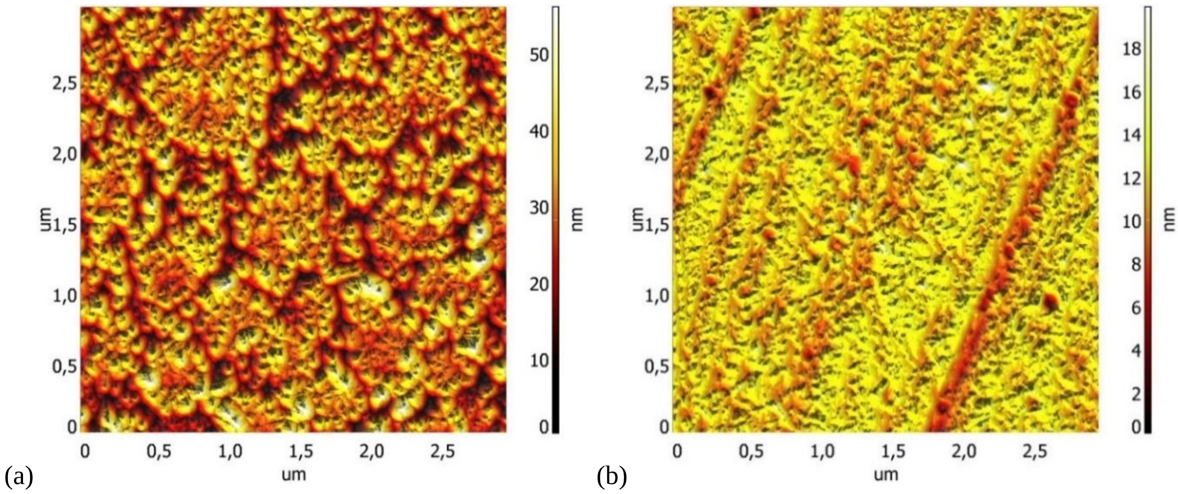


Figure 2. Topography of single- (a) and double-layer (b) films (scans size is 3 x 3 μm).

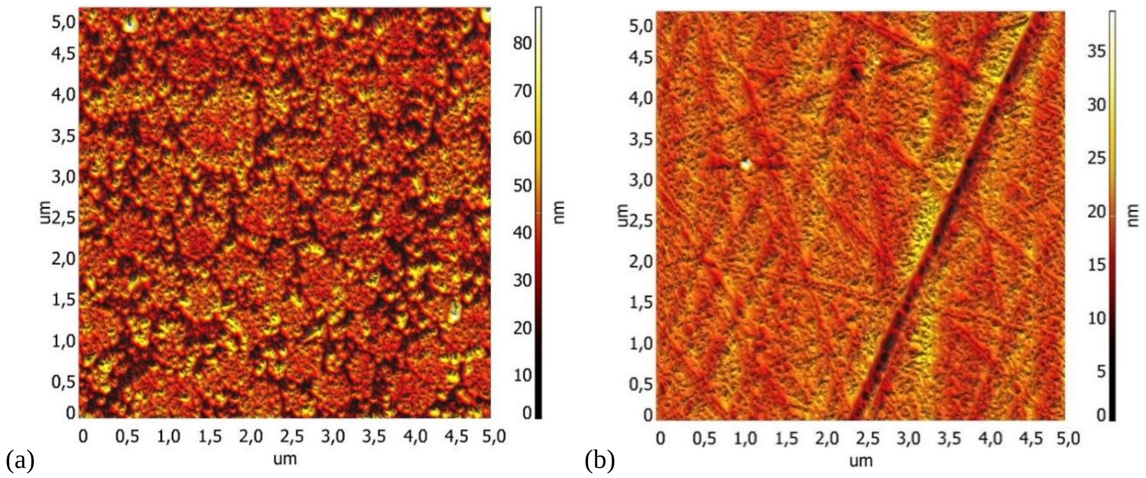


Figure 3. Topography of single- (a) and double-layer (b) films (scans size is 5 x 5 μm).

Therefore, application of simultaneous crystallization annealing of bottom Bi-substituted iron garnet layer and the top layer of silicon oxide reduce the surface roughness of layers by 3-5 times.

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1. A.N. Shaposhnikov, A.R. Prokopov, A.V. Karavainikov, V.N. Berzhansky, T.V. Mikhailova, V.A. Kotov, D.E. Balabanov, I.V. Sharay, O.Y. Salyuk, M. Vasiliev, V.O. Golub, *Materials Research Bulletin* **55**, 19 (2014).